Pacific Islands Fisheries Science Center

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December 2006

Administrative Report H-06-04

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ABSTRACT

Sagittal otoliths of swordfish, *Xiphias gladius*, from the central North Pacific were examined for ridges on the proximal surface of rostrums and for internal annuli in whole and sectioned specimens to evaluate whether features can be counted and used to estimate swordfish age. Ridges were only partially discernible on rostrums of sagittae magnified in thermo prints and photographs; internal annuli were less visible in the photographs. Alternating opaque and translucent bands were apparent in transverse sections of sagittae and opaque bands were counted as annuli for 583 fish, but the rate of annulus formation was not determined. In lieu of validation, the numbers of annuli tallied using sagittae were compared with annuli counted in sectioned fin rays of 322 matched (same fish) specimens (representing 13 age groups based on fin rays). We thereby evaluated whether ages estimated from counts of annuli in otolith and fin ray sections were equivalent. Nonparametric, paired-sample tests accepted the null hypothesis that the median difference was zero for females in age-groups 1 through 9 ($P \geq 0.05$); however, this null hypothesis was rejected when all fish of both sexes in age-groups 1 through 12 and males in age-groups 1 through 6 were compared ($P < 0.05$). Age-bias plots based on annuli counts in sagittae and fin rays from the same swordfish indicated that ages estimated from otoliths were generally older than ages estimated using fin rays for all age groups and for females and males separately, despite large variations in estimates within each age group. Annuli and presumed daily growth increment counts in paired sagittae of 19 small swordfish indicated that the first annulus was correctly identified using sagittae.

Weights of sagittae increased with growth in fish length. Sagittae tended to be heavier in males than in females of equal body lengths.

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INTRODUCTION

Swordfish, *Xiphias gladius,* landings from the central North Pacific by Hawaii-based longliners rose from 23 metric tons (t) in 1989 to 1591 t in 1990 as vessel numbers increased from 10 to approximately 50 (Dollar[1]). Because of increases in catch and effort and concern over their effect on the swordfish stock(s), in 1991 the National Marine Fisheries Service (NMFS) in Honolulu began comprehensive studies on swordfish biology. One of the principal goals was to estimate age and growth which, with data collected by the federally mandated logbook and fishery observer program initiated in 1991 (Dollar and Yoshimoto[2]), would provide needed information for the assessment of the swordfish stock(s). Although some restrictions have been placed on U.S. longliners for swordfish fishing in the central North Pacific (Ito and Coan[3]), this research has continued through 2006.

Three primary methods have been used in age and growth studies of swordfish from the Pacific, Atlantic, and the Mediterranean and surrounding seas: (1) length frequency distributions (Yabe et al., 1959; Kume and Joseph, 1969; Beckett, 1974; Ovchinnikov et al., 1980; De Metrio and Megalofonou, 1988; Haist and Porter, 1993); (2) growth bands in fin rays (Berkeley and Houde, 1983; Tsimenides and Tserpes, 1989; Megalofonou et al., 1991; Moreira, 1991; Ehrhardt, 1992; Tserpes and Tsimenides, 1995; Esteves et al., 1995; Ehrhardt et al., 1996; Castro-Longoria and Sosa-Nishizaki, 1998; Aliçli and Oray, 2001; Sun et al., 2002; Arocha et al., 2003; DeMartini et al. (in press); and (3) growth features either on or in sagittae (Radtke and Hurley, 1983; Wilson and Dean, 1983; Prince et al., 1988; Esteves et al., 1995; Megalofonou et al., 1995; Castro-Longoria and Sosa-Nishizaki, 1998). Bands have also been described as present in vertebrae and opercula of swordfish. However, many researchers have questioned the suitability of vertebrae and opercula for ageing swordfish. Beckett (1974), for example, reported that bands were not "consistently interpretable" in vertebrae and opercula (and also for rays) of fish from the western North Atlantic and Esteves et al. (1995) counted more annuli in vertebrae than in sections of the second spine (ray) of first anal fins and whole sagittae of female swordfish landed in the Azores. Uchiyama et al. (1998) recorded more bands in the 23rd and 24th vertebrae than in sectioned second rays of first anal fins of swordfish caught in the central North Pacific. Previously, Artüz (1963) found no "notable appearance of annual markings" in a cursory look at vertebrae and opercula of swordfish from the Sea of Marmara.

In a preliminary ageing study of swordfish from the central North Pacific, Uchiyama et al. (1998) counted presumed daily growth increments (DGI) on the rostrums of sagittae and presumed yearly annuli in crosssections of fin rays. They also saw external ridges on rostrums

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[1] Dollar, R. A. 1991. Summary of swordfish longline observations in Hawaii, July 1990–March 1991. Southwest Fish. Sci. Ctr. Admin. Rep. H-91-09, 13 p.
[2] Dollar, R. A. and S. S. Yoshimoto. 1991. The federally mandated longline fishing log collection system in the western Pacific, December 1991. Southwest Fish. Sci. Ctr. Admin. Rep. H-91-12, 35 p.
[3] Ito, R. Y. and A. L. Coan, Jr. 2002. U. S. swordfish fisheries in the North Pacific Ocean. Working paper ISC SWO-WG/02/01 presented at the Third Interim Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), January 25–26, 2002, Nagasaki, Japan.

that were similar to those described by Radtke and Hurley (1983) and recommended them for further investigation. Fishery scientists at the NMFS Honolulu Laboratory began a definitive study on age and growth of swordfish from the central North Pacific using DGI on sagittae of fish < 22.7 kg round weight (so-called "rats"; Humphreys and Nishimoto, in prep.) and bands in crosssections of the second ray of the first anal fin (henceforth "fin rays") of swordfish of exploitable sizes (DeMartini et al., in press) The suitability of using ridges on rostrums and annuli in whole and sectioned sagittae to age swordfish was examined in this study. The relationship between length of swordfish and the weight of their sagitta(e) was also estimated.

MATERIALS AND METHODS

Collection and Storage of Otoliths

Sagittae were extracted from braincases of swordfish landed with longline gear deployed from the NOAA ship *Townsend Cromwell* in 1992 and 1993 and from commercial fishing boats during 1994–1998. Samples were obtained from fish caught in all months and between lat. 14° N – 45° N, long. 140° W – 175° E, the area worked by the Hawaii-based longline fleet (Ito et al., 1998).

NMFS biologists on the research vessel and fishery observers on commercial boats gathered samples. Specimen number, date of capture, and geographical location of the longline set along with fish length and sex were recorded whenever possible. Lengths were measured in a straight line from the posterior eye orbit to the fork in the caudal fin (EFL) to 0.1 cm on the research vessel and to the nearest centimeter on commercial boats. First anal fins and heads or semicircular canals were removed at sea, frozen, and returned to shore. Sections of gonads were also collected from all fish caught on the research vessel and randomly subsampled on the commercial boats to confirm, microscopically, the identification of sexes made at sea and to establish the developmental stages of testes and ovaries (DeMartini et al., 2000).

Scientists on the research vessel retained heads of swordfish, and observers extracted semicircular canals with otoliths while at sea. Semicircular canals were excised from craniums at the shore laboratory, placed in tap water, and sagittae separated from their sacculi under a dissecting microscope. After soft tissue was removed with a small paint brush, sagittae were rinsed in distilled water and stored in glass vials partially filled with 95% (misprinted in published report as 75%) ethanol (Uchiyama et al., 1998). For semicircular canals collected by the observers, sagittae, lapilli and asterisci (if present) were cleared of their sacs while in tap water, cleaned of soft tissue with a small paint brush in tap water or in 5.25% sodium hypochlorite (Clorox[4]) diluted further with water, rinsed in distilled water, and stored in glass vials filled with 95% ethanol.

[4] Reference to trade names of commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

External Morphology of Sagittae

An image of the proximal (sulcus) side of a swordfish sagitta, magnified 48x with a scanning electron microscope (SEM), is illustrated in Figure 1. The description of its morphology follows Kalish et al. (1995).

Sagittae of swordfish from the central North Pacific are relatively flat proximo-distally in small fish, but sulci become deeper with increase in otolith size. Rostrums are generally longer than antirostrums and join near the core to form an anterior (excisural) notch. A similar, posterior notch may be present, usually in sagittae of smaller fish, or the postrostrum may be incompletely or completely closed. Some ridges may often be visible on the proximal surface of rostrums (Fig. 1).

Weights of Sagittae

Sagittae were weighed to 0.01 mg with a Mettler AE240 micro-balance. Preparation for weighing began by removing sagittae from storage in ethanol and allowing the alcohol to evaporate at room temperature. They were then placed individually in a 1-dram glass vial that had been dried in an oven for 2–3 h at 80^{o} C. The vials were capped with a plastic lid containing two or three small pellets of anhydrous $CaSO_4$ wrapped in lint-free wipers and stowed in a desiccator with more anhydrous $CaSO_4$. About 72 h later sagittae were removed from vials, immediately placed on weighing paper on the pan of the micro-balance, and weighed. After initial weighing, sagittae were returned to vials and desiccator for 24 h before being reweighed. The mean of the two readings was used (listed in the Appendix).

External Ridges on Rostrums and Internal Bands

The three authors attempted to count external ridges on rostrums and translucent bands in whole sagittae using images of otoliths in thermo prints and photographs. Thermo prints were prepared for the proximal surface of whole otoliths or rostrums using a Zeiss DSM 963 SEM. Entire otoliths were enlarged up to 70x or rostrums were magnified in sections by 70x – 200x. A complete image of the rostrum was constructed by joining the consecutive sections of the thermo prints. Ridges were expected to be apparent on the rostrums. Photographs of the proximal surface or proximal and distal sides of sagittae were taken with a Cannon AE1 camera and a 2x Cannon extender mounted on a dissecting microscope. These sagittae were magnified 6 – 10x while immersed in ethanol, distilled water, paraffin oil, or glycerol over a black velvet background to expose internal bands and external ridges.

Transverse Sections of Sagittae

At the beginning of this study, 10 sagittae from swordfish caught in the central North Pacific were sent to Charles Wilson's laboratory at Louisiana State University in Baton Rouge for an opinion as to whether opaque and translucent bands could be seen in transverse sections. At the same time, one or two sagittae were also processed in the frontal, sagittal, and transverse planes at the Honolulu Laboratory.

After determining that alternating opaque and translucent bands could be seen in transverse sections of sagittae, specimens collected on the research vessel and those previously weighed or scanned with an SEM were sectioned along with randomly selected otoliths from commercial longline catches. Entire collections of sagittae from individual commercial longline trips were prepared later and those of rats and fish of $\geq$ 200 cm EFL were chosen to increase the sample size of small and very large fish. Each opaque band was counted as an annulus.

Sagittae were sectioned after embedding them in clear casting resin. To form molds, resin was dripped in bowls of glass depression slides that were coated with nonstick cooking spray or oil. About 2 h later, the distal side of a sagitta was placed on the hardening resin with a numbered strip of paper to identify the sample. The entire otolith and portion of the paper were covered with more resin to form a complete mold.

Approximately 24 h later, sectioning of sagittae began by manually grinding the molds from the anterior edge of the sagitta on 400-, 800- and 1200-grit silicon carbide sandpapers placed on a smooth counter top. Reduction of the mold continued until the anterior notch of the sagitta was reached. The mold was then rotated 180^{o} and the posterior (postrostrum) side reduced until about 5 mm of the mold remained. At this stage, the rostral end of the sagitta was glued to a microscope slide with a mounting medium (Cytoseal 60).

After the mounting medium was dried overnight to ensure that the mold was securely attached to the glass slide, the microscope slide was held and the posterior side of the sagitta sanded manually. Reduction of the mold and sagitta was made on 800- and 1200-grit sandpaper laid on a counter top with water sometimes added. The process of reduction and inspection of the section under a dissecting microscope continued until the preparer concluded that opaque bands were clear enough to enumerate or that they would not become more apparent by creating a thinner section.

Opaque bands were counted as annuli using a dissecting microscope and transmitted light at a magnification of 40x. Generally, bands were enumerated in the dorsal half of the sagitta where they were more defined (Fig. 2). If opaque and translucent bands were difficult to discern in the first sagitta sectioned, the second of the pair, if available, was also prepared and the section with the clearer opaque bands was used.

Because opaque bands were often difficult to enumerate, techniques used to help differentiate alternating opaque and translucent bands involved details of section processing, use of microscope, and positioning of the microscope slide. Frequent inspections of the sections during sanding aided in determining when opaque and translucent bands became exposed. If the sections were cut too thin, opaque and translucent bands became difficult to differentiate because of lack of contrast. Changing the intensity of the light source, reducing the sharpness of the bands by altering the focus of the microscope, and turning the microscope slide over and looking at the section through the glass were often helpful.

One reader made all annuli counts. Initially, the best estimate of the numbers of opaque bands in a sagitta was recorded at three different sessions. These readings were discarded since the first annulus was thought to have been misidentified in some of the earliest readings. Therefore, all samples were reread three or four times. The first reading of all sectioned sagittae took about a week to complete. The second counts were made about 4 months after the first and the third about a week after the second with the order in which the samples were read remaining the same. If all three readings were different for a sample, a fourth count was made.

Data Analysis

Statistical analyses and summaries were completed separately for males and females, and, for heuristic reasons, for all sexes combined. Wilcoxon sign ranks tests were used (Statgraphics *Plus*, vers. 3.3, Manugistic, *Inc.*, Rockville, MD) to evaluate whether age groups derived from annuli counted in sectioned second rays of the first anal fins (DeMartini et al., in press) and sectioned sagittae of the same specimens were equal. For both hard parts, age groups were based on annuli that were completely formed. For example, if two whole annuli or two whole annuli and a developing annulus at the margin were tallied, the fish was placed in age-group two. Age-frequency tables and age-bias plots (Campana et al., 1995) were also created to compare age groups derived from the sagitta and fin ray of the same fish. Analysis of covariance (SAS for Windows, vers. 8, SAS Institute, *Inc.*, Cary, NC) was employed to compare sagitta weight and EFL of male and female swordfish.

RESULTS

External Ridges on Rostrums and Internal Bands in Whole Sagittae

Thermo prints of the proximal surface of sagitta(e) for 141 swordfish, including higher magnification of 100 rostrums, were produced with an SEM in an attempt to identify ridges on rostrums. The samples were from 60 females of 67–236 cm EFL, 72 males of 58–196 cm EFL, and 9 without length measurement or known sex (Appendix). Sagitta(e) from 94 of the 98 swordfish (50 males, 45 females, and 3 with unknown sex) that were photographed using light microscopy were also scanned with the electron microscope (Appendix).

Some ridges were seen in the thermo prints and photographs; however, they were only partially discernible on the majority of rostrums. Translucent bands were noted in rostrums and postrostrums in the photographs, but they were usually less visible than ridges. Translucent bands, if seen, were clearest in sagittae submerged in paraffin oil.

Annuli in Transverse Sections of Sagittae

Sagittae were sectioned for 586 swordfish; 10 at Louisiana State University, following the method of Wilson and Dean (1983), and 576 at the Honolulu Laboratory. Opaque bands were counted in 583 swordfish; one microscope slide was misplaced and two others were not read because of a missing core.

Based on a minimum of two of the three or four readings of the sectioned sagitta being identical, annuli counts from 577 of the 583 swordfish were accepted. The six sections that were deemed unreadable (four different readings) were from four females of 228–237 cm EFL and two males of 208 and 220 cm EFL. Additionally, annuli counts in sagittae from 20 fish were not included in any of the analyses because fish lengths were not available.

The remaining 557 fish consisted of 329 females of 52–259 cm, 224 males of 53–228 cm and 4 of unknown sex (Appendix). The length frequency distribution indicated nearly equal representation of genders below 100 cm, more males than females in the 100–139 cm range, similar numbers for sizes 140–169 cm, and more females > 170 cm (Fig. 3). The samples included only 56 swordfish that were caught during the July–September quarter, when longline fishing effort for swordfish is lowest (Ito and Machado[5]), and 501 swordfish from October through June (Fig. 4). Monthly sample sizes were nearly equal for males and females except for January, March, April, August, and November when females outnumbered males by about 2:1. Although specimens included in the study were caught between 1992 and 1998, most (459) were caught from 1995 to 1997.

The numbers of opaque bands per otolith, excluding any band that appeared to be forming on the margin, ranged from 0 to 23. Annuli were clearly or poorly defined and narrow or broad with borders and spacing variably diffused. These bands became more distinct, narrower, and more evenly spaced toward the margin (Fig. 2).

Gender did not appear to influence the quality of annuli nor were they more easily defined in the left or right sagitta. Relatively clear bands were seen in the first sagitta sectioned for 141 of 226 (62.4%) males and 210 of 333 (63.1%) females. Equivalent percentages implied that clarity of annuli was not gender specific. When both sagittae of 115 swordfish were sectioned, annuli were of similar quality in each pair from 46 fish (40%). Opaque bands were seen more clearly in one of the two paired otoliths in the other 69 (60%) cases, 36 in left and 33 in right sagittae. This suggested that clarity of bands differed

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[5] Ito, R. Y. and W. A. Machado. 1999. Annual report of the Hawaii-based longline fishery for 1998. Southwest Fish. Sci. Ctr. Admin. Rep. H-99-06, 62 p.

randomly between the left and right sagittae of the same fish and that differences may have been artifacts of sectioning.

Corroboration of Annuli Counts

The rate of annuli formation in sagittae was not validated. Instead, comparisons were made among age groups estimated from annuli counts in the sectioned second ray of the first anal fin (DeMartini et al., in press) and annuli counts in the sectioned sagitta of the same fish. Three hundred and twenty-two fish and 13 age groups (based on annuli counts for fin rays) had age estimates derived from both hard parts of the same swordfish. Length frequency distributions (Fig. 5) indicated a 52–259 cm EFL range with nearly equal sampling of genders at ≤ 190 cm and approximately five times as many females as males at > 190 cm. The mean coefficient of variation (CV; Chang, 1982) based on three independent annuli counts of sagittae for the 322 swordfish used in the comparison was 19.13%, similar to the mean CV (19.98%) for three counts of annuli in sagittae of all 583 fish.

Paired-sample tests for age-groups 1–12 (n = 273) were conducted to determine whether annuli counts in sagittae and fin rays were equal. Wilcoxon matched-pairs signed-ranks tests were appropriate since the data were not normally distributed. The null hypothesis that the median difference was zero between sagitta and fin ray counts was rejected at the 95% confidence level ($P < 0.05$).

Similar tests were conducted individually for males and females. For males, age-groups 1 through 6 (n = 91) were used because older age groups had less than five samples each. For females, only age-groups 1 through 9 (n = 155) were employed although there were six samples in age-group 10 and seven in age-group 11. Null hypotheses that median differences were zero were accepted with 95% confidence for females but not for males.

Summaries of age groups based on readings from sagittae relative to fin rays (Tables 1a–c) and age-bias plots (Figs. 6a–c) were also created using 13 age-groups for both genders combined and separately for males and females. For each age group, the means of ages estimated from annuli counted in sagittae were plotted against analogous ages derived from annuli counts in fin rays (DeMartini et al., in press). The 95% confidence intervals of annuli counts from sagittae do not imply statistical significance in the comparisons, but are presented to show their variability about the mean. For each age group, biases for annuli counts in sagittae relative to annuli counts in fin rays are mostly positive. However, except for males, the plots did not indicate greater deviation of the means from the 1:1 line with increasing age. The variability of ages estimated from sagittae relative to those of fin rays, however, was large (Tables 1a–c).

Further comparisons were made to determine whether the location of the first annulus in the sectioned sagitta was correctly identified by comparing presumed DGI (Uchiyama et al., 1998; Humphreys and Nishimoto, in prep.) with counts of annuli in paired sagittae of 19 fish of 55–141 cm EFL. Data on EFL, DGI counts converted to years, and age groups estimated from annuli counts are listed in Table 2.

Sagitta Weight Versus Swordfish Length

Sagittae were weighed for 82 female swordfish that ranged from 71 to 236 cm EFL and 91 males that measured 64–228 cm EFL. These included both members of the pair from 114 swordfish and a single sagitta from 59 fish. Each sagitta weighed between 0.14 and 4.19 mg. Wilcoxon matched-pairs signed-ranks test indicated that there was no statistical difference between the weights of the left and right sagitta of the same fish at the 95% confidence level (P = 0.79).

The weight of a sagitta or an average of both was plotted against fish length, by sex, in Figure 7. After log transformation, regression lines of sagitta weights versus swordfish lengths for males and females were compared (Fig. 8). Sagittae from male swordfish weighed, on average, about 14% more than sagittae of females at a given body length (ANCOVA on sex effects: $F_{1,\,169} = 16.1$, $p < 0.0001$).

DISCUSSION

Estimating Ages of Swordfish Using Sagittal Otoliths

Proximal surfaces of rostrums were initially examined for external ridges that might possibly be used to age swordfish. Some ridges were visible in the thermo prints and photographs, but others that were expected because of the locations of the visible ridges and the sizes of the otoliths were not seen or were difficult to discern. Similar results were reported by Wilson and Dean (1983) for swordfish caught in the western North Atlantic and by Castro-Longoria and Sosa-Nishizaki (1998) for fish from Baja California. In addition, the ventral edge of some of the largest sagittae that were extracted, but not used in this study, often appeared flat and worn. If ridges were present in that area, they would be difficult to detect. Annuli in photographs of whole sagittae were usually less visible than ridges. Therefore, neither ridges nor internal annuli in whole sagittae are recommended for ageing swordfish from the central North Pacific.

Alternating opaque and translucent bands were seen in transverse sections of sagittae and were reported to be similar to annuli present in swordfish from the North Atlantic by the scientist at Louisiana State University. Because Wilson and Dean (1983) indicated that these features were laid down annually for swordfish from the North Atlantic, sagittae of swordfish from the central North Pacific were sectioned transversely and annuli counted in an attempt to age these fish.

Corroboration of Annuli in Sagittae

Relative Marginal Increment (RMI) analysis has been used to validate the rate of formation of opaque bands in swordfish fin rays (Ehrhardt, 1992; Sun et al., 2002; DeMartini et al., in press), but this technique was not pursued because the diminutive size and pronounced curvature of sagittae made accurate measurements from focus to annuli and to the otolith margin questionable. For example, regarding size, the anterio-posterior and dorso-ventral measurements of a sagitta from a female swordfish of 190 cm EFL and a male swordfish of 184 cm EFL were 3.9 mm x 1.8 mm and 4.5 mm x 1.8 mm. Another consideration for not using RMI was an inability to determine whether an annulus at the margin was complete.

Comparisons were made between presumed DGI and annuli counted in fin rays of the same fish. Except for the largest fish in the comparison, DGI counts suggested that the first annulus in sectioned sagittae was correctly identified. The discrepancy in age estimates of 1.6 yr from DGI and age-group 4 from annuli counts may have been a result of either misidentification of annuli, undercounting of DGI, or both.

In lieu of validation, age groups estimated using the sagitta and fin ray of the same fish were compared to evaluate whether the numbers of annuli counted in both hard parts were equal. Wilson (1984) employed this method to verify that swordfish < 6 yr of age could be estimated using annuli counts in sectioned sagitta and fin ray of the same fish. Similarly, Castro-Longoria and Sosa-Nishizaki (1998) argued that correspondence between DGI in sagittae and annuli in the second rays of the first anal fins verified fin ray counts for swordfish < 3 yr old.

Wilcoxon matched-pairs signed-ranks tests indicated that the numbers of annuli counted in sagittae of female swordfish in this study were similar to that of fin rays for age-groups 1 to 9, but not for males in age-groups 1 through 6 and for all sexes in age-groups 1 through 12. The rejection of the hypothesis that median differences was zero for all samples was likely related to the large positive bias introduced by older male swordfish as indicated in the age-bias plot. The possibility exists that disproportionately more bands are present in sagittae from older males; however, we can offer no explanation as to why this might be so.

Overall, there was a tendency to count more annuli in a sagitta than in a fin ray of the same fish. Riehl (1984), Esteves et al. (1995) for female swordfish, and Wilson (1984) for swordfish ≥ 6 yr old also reported similar results. Riehl (1984) suggested that differences in annuli counted in fin rays in his study and external ridges enumerated in sagittae by Radtke and Hurley (1983) for older female swordfish may be a result of spawning checks resembling growth marks in sagittae but not fin rays. This observation was not seen in female swordfish from the central North Pacific, where annuli counts in sagitta and fin ray of the same fish, at least in the age groups compared, were statistically similar.

Alternating translucent and opaque bands were visible in sectioned sagittae and the numbers of bands in sagittae and fin rays were equivalent for females in age-groups 1 through

9, but not for males in age-groups 1 through 6. A large problem with these comparisons, however, was the subjectivity involved in the identification of annuli as evidenced by the high coefficient of variation of annuli counts in sagittae of nearly 20% by a single reader in this study relative to that of sectioned fin rays (within-reader CV = 12-13%: DeMartini et al., in press).

If one could count annuli accurately and their rate of formation was validated, sagittae might be used to estimate average sizes at age as seen in the younger age groups of females. One major disadvantage in using sectioned sagittae for ageing swordfish, however, is that accurate measurements of distances from focus to annuli could not be obtained using the described method of crosssection preparation. This would preclude back-calculations of length-at-age that are necessary for quantitative characterization of growth curves.

Sagitta Weight Versus Swordfish Length

Sagittae were weighed because of the potential for using otolith weight in either multivariate- or multiple regression-based estimations of fish age (Boehlert, 1985). Templeman and Squires (1956), Secor and Dean (1989), and others also noted correlations between fish age and otolith weight for other fish species.

Sagittae of larger males were appreciably heavier than those of females of equal body length for swordfish caught in the central North Pacific. This contrasts with varying patterns observed for swordfish collected elsewhere. Castro-Longoria and Sosa-Nishizaki (1998) found differences in weights of sagittae for males and females of equal lengths from the eastern North Pacific; however, based on the equations reported in their study, those from males weighed more than females of equal lengths at smaller sizes and less than females of equal lengths at larger sizes. Wilson (1984) found no difference in the weights of sagittae for males and females of equal lengths.

Sagitta weight and age of swordfish from the central North Pacific may be related and may be worth pursuing. However, no attempt was made to test the possible correlation between estimated age and sagitta weight because questions remain regarding the accuracy of annuli counts for sagittae.

Cost Effectiveness

The time (cost) required to prepare swordfish otolith crosssections is appreciably greater than that required to prepare sections of swordfish fin rays. Fin rays have already been successfully employed in age and growth studies of many swordfish stocks worldwide. This precedent argues that a better and less expensive way of deriving back-calculated size at age in years using otolith sections needs to be developed if one were to use sectioned otoliths instead of sectioned fin rays for ageing swordfish.

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TABLES

Table 1a.--Age-frequency table comparing age groups based on fin rays and sagittae of all swordfish of both sexes pooled.

Age group (sagittae)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 . .	23	Total
Age group (fin rays)																					
0	**43**	4	1	1																	49
1	11	**29**	9	7	1																57
2	2	8	**16**	8	4	4	2			1											45
3			2	**5**	3	2	2	3													17
4				5	**5**	4	2	2	1												19
5				3	4	**3**	4	4	1		1	2			1						23
6			2	4	5	4	**3**	5	1	1	4	1	2								32
7					2	3	3	**5**	4	2	2	1	2	2			1				27
8				1		1	4	5	**1**	1	2		2	1		1			1		20
9					1	1	2	1	1	**2**	1	6	1							1	17
10								2	1			1		1			1	1			7
11								2		2		**2**		1							7
12														2							2

Table 1b.--Age-frequency table comparing age groups based on fin rays and sagittae of female
swordfish.

Age group (sagittae)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 .. 23	Total
Age group (fin rays)																				
0	**25**	2		1																28
1	5	**15**	3	1	1															25
2	2	4	**9**	2	1	1	1													20
3			2	**1**	2	2		1												8
4				3	**3**	2	1	1												10
5				3	3	**3**	2	3	1		1									16
6			1	3	3	3	**2**	3	1		4	1	2							23
7					2	3	3	**4**	4	2		1	1	2			1			23
8				1		1	3	5	**1**	1	2		1	1						16
9					1	1	1	1	1	**2**	1	5	1							14
10								2	1			1		1			1	1		7
11								2		2		**1**		1						6
12														2						2

Table 1c.--Age-frequency table comparing age groups based on fin rays and sagittae of male swordfish.

Age group (sagittae) / Age group (fin rays)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 ..	23	Total
0	**15**	1	1																		17
1	6	**14**	6	6																	32
2		4	**7**	6	3	3	1			1											25
3				**4**	1		2	2													9
4				2	**2**	2	1	1	1												9
5					1		2	1				2			1						7
6			1	1	2	1	**1**	2		1											9
7								**1**			2		1								4
8							1						1			1			1		4
9							1					1								1	3
10																					0
11												**1**									1
12																					0

Table 2.--Comparisons of ages based on DGI counts on the rostrum of sagittae (Uchiyama et al., 1998; Humphreys and Nishimoto, in prep.) and annuli counted in transverse sections of the second sagitta of the same swordfish.

EFL (cm)	Sex	Age (DGI) (Years)	Age (Annulus) (Year group)	Month Caught
55	Male	0.2*	0	October
56	Female	0.2*	0	October
58	Male	0.3*	0	October
60	Female	0.3*	0	October
63	Female	0.3*	0	October
74	Female	0.5*	0	October
74	Female	0.4*	0	October
77	Unidentified	0.8	0	March
81	Unidentified	0.8*	1	April
88	Male	1.1 *	1	June
100	Female	1.5*	0	November
107	Female	1.4	2	April
108	Female	1.5	1	April
110	Female	1.4*	1	November
115	Female	1.9*	2	August
116	Male	1.4*	2	April
118	Male	1.5*	1	May
118	Female	1.7*	2	June
141	Male	1.6	4	April

*Age estimates based on the mean of three readings by second reader in Humphreys and Nishimoto, in prep.

FIGURES

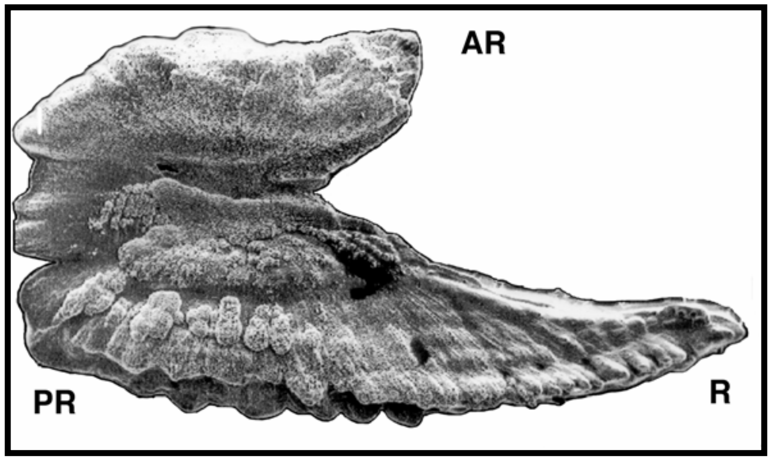

Figure 1.--Scanning Electron Microscope thermo print (48x) of the proximal (sulcus) side of the left sagitta from a 107 cm EFL, female swordfish (AR = antirostrum, R = rostrum, PR = postrostrum).

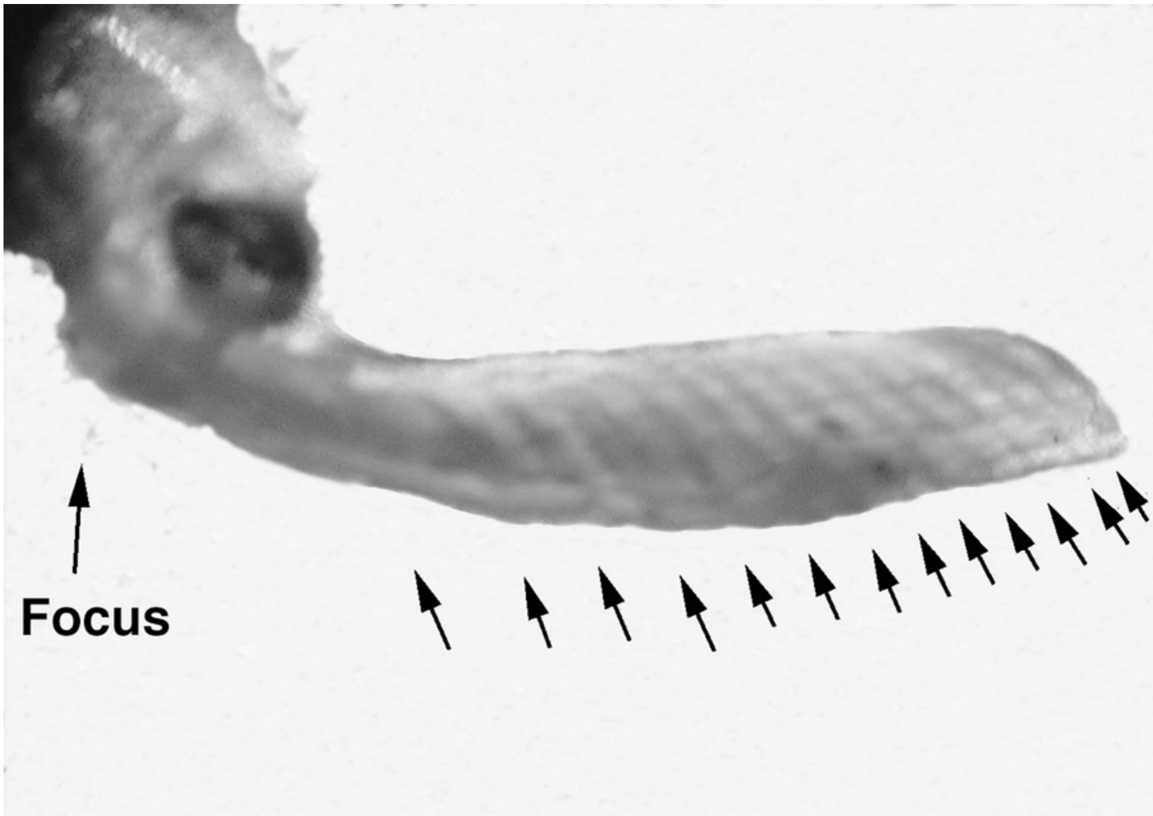

Figure 2.--Transverse section of a sagitta showing broader, darker, opaque bands nearer the focus and closer-spaced, more defined and narrower bands toward the dorsal margin.

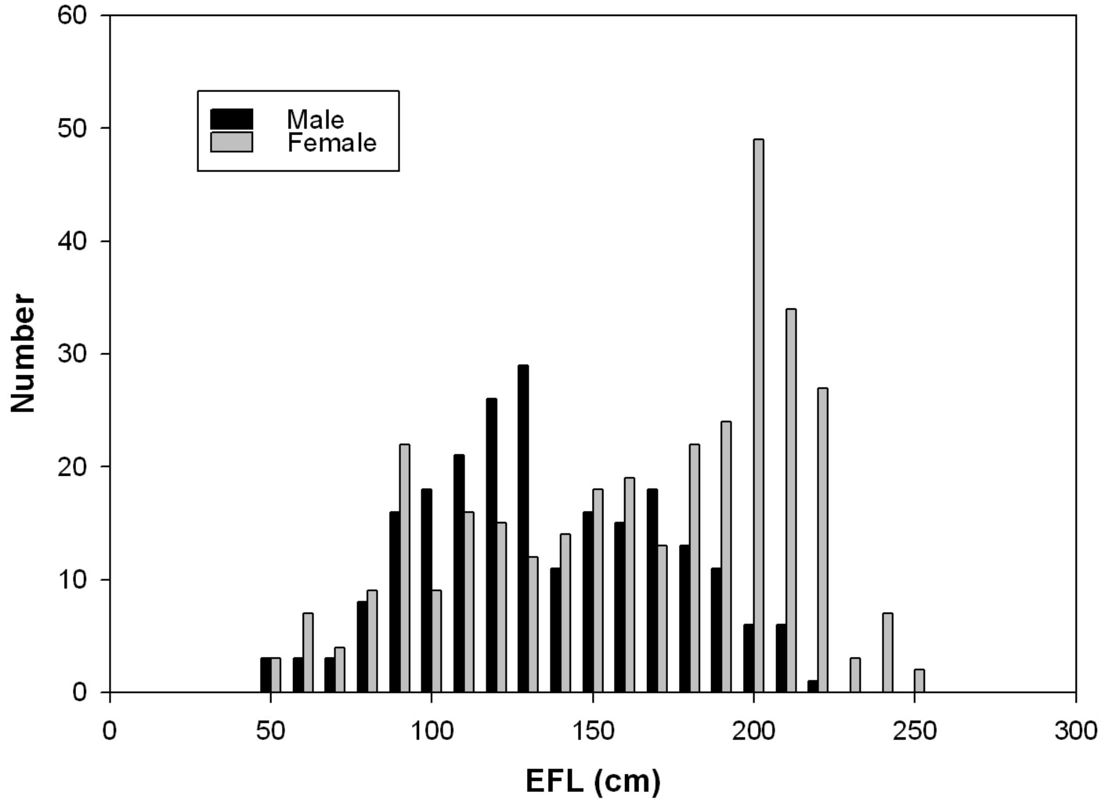

Figure 3.--Length frequency distribution by 10 cm eye-to-fork length of male (*n* = 224) and female (*n* = 329) swordfish used in study.

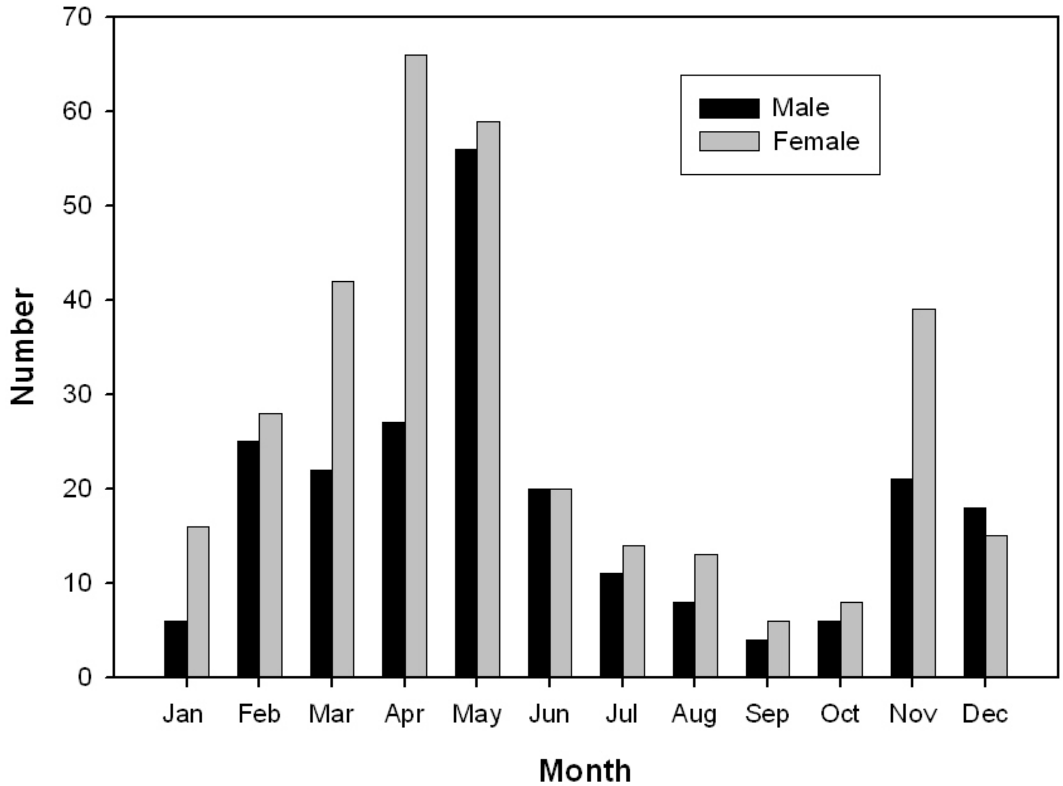

Figure 4.--Number of samples by month of capture for male (n = 224) and female (n = 326) swordfish used in study.

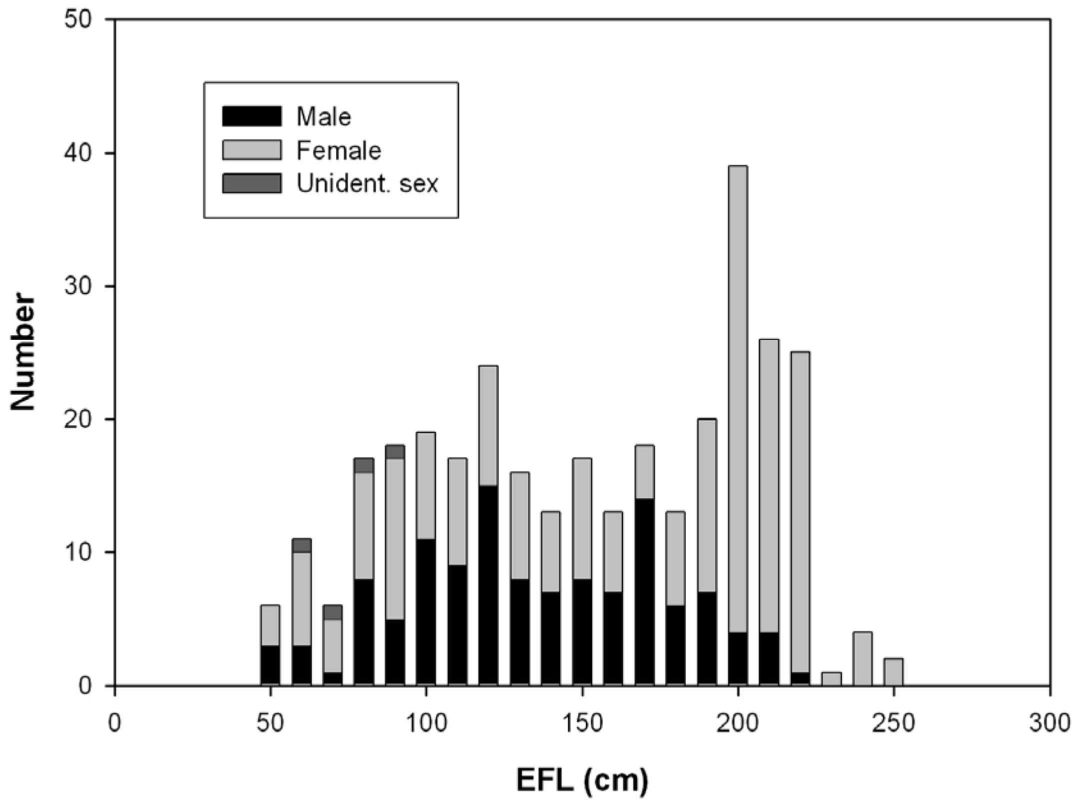

Figure 5.--Length frequency distribution by 10 cm eye-to-fork length of swordfish used in age-bias plots to compare age groups based on annuli counts for the fin ray and sagitta of the same fish (120 males, 198 females and four with unknown sex).

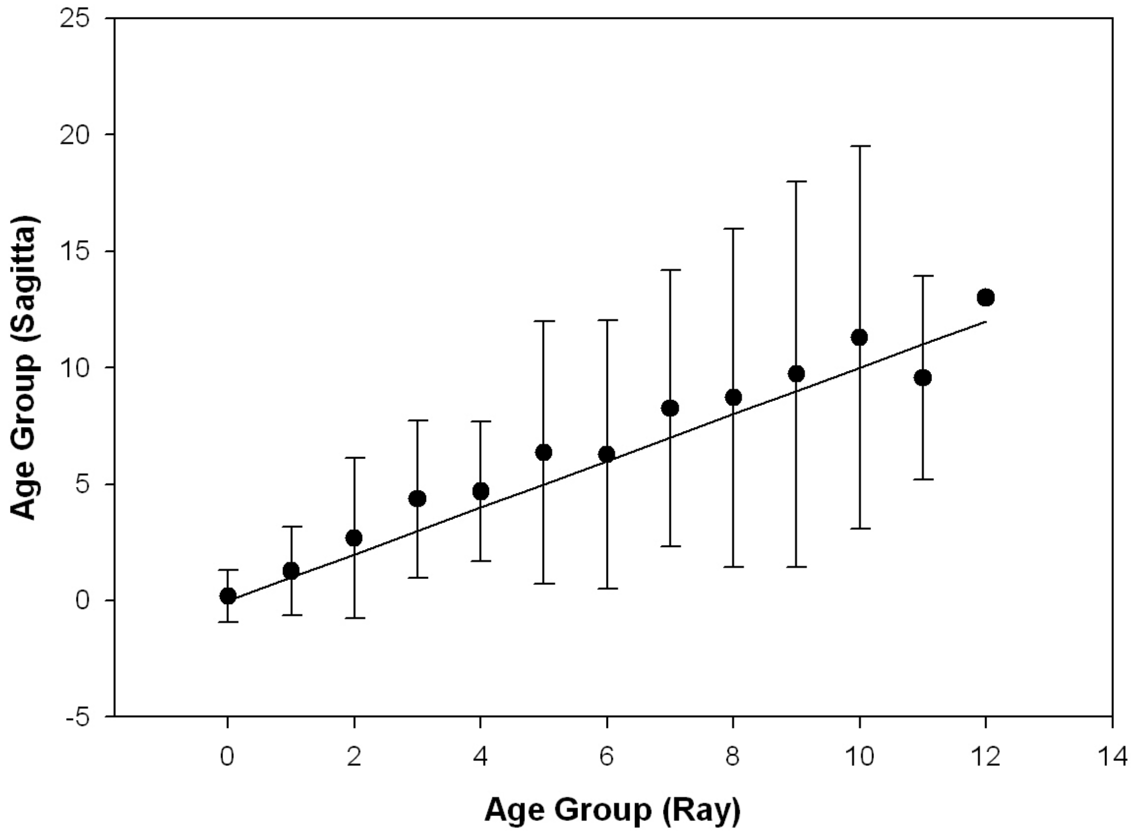

Figure 6a.--Age-bias plot comparing age groups estimated from fin ray and sagitta of the same

male and female swordfish pooled (*n* = 322). The straight line is the 1:1 relationship. Closed circles are means of age groups from sagittae and vertical lines indicate 95% confidence intervals.

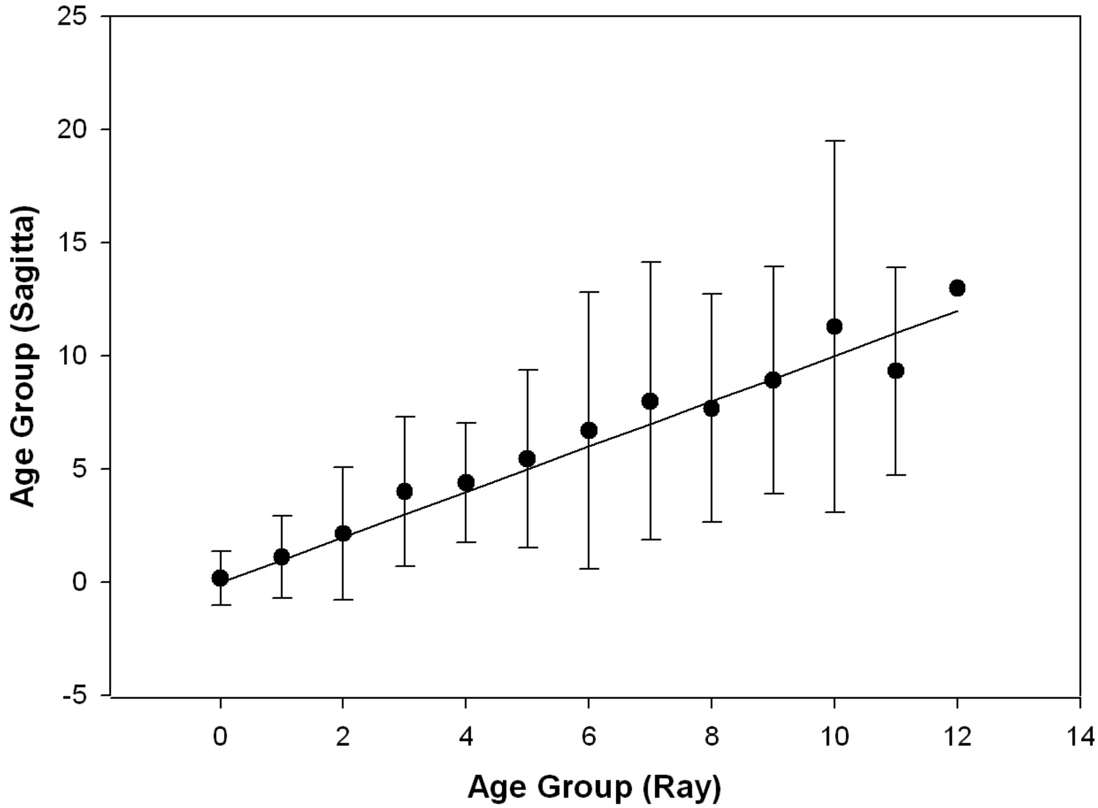

Figure 6b.--Age-bias plot comparing age groups estimated from fin ray and sagitta of the same female swordfish (*n* = 198). The straight line is the 1:1 relationship. Closed circles are means of age groups from sagittae and vertical lines indicate 95% confidence intervals.

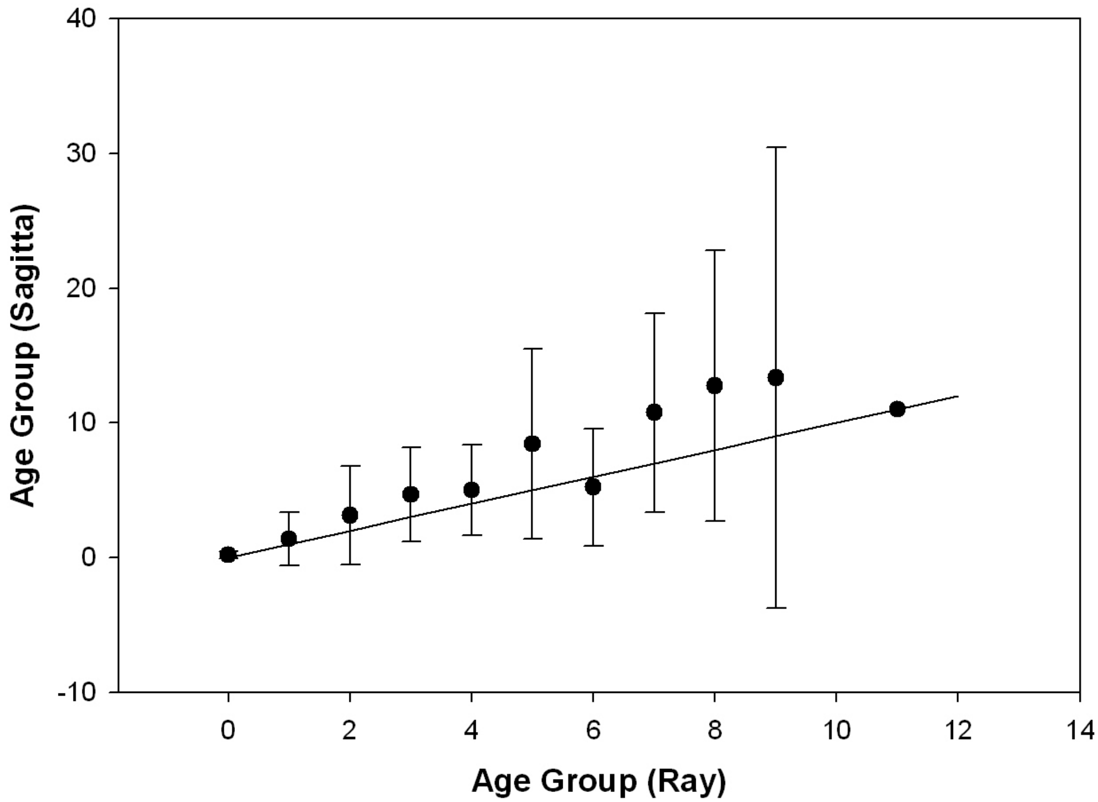

Figure 6c.--Age-bias plot comparing age groups estimated from fin ray and sagitta of the Same male swordfish (n = 120). The straight line is the 1:1 relationship. Closed circles are means of age groups from sagittae and vertical lines indicate 95% confidence intervals.

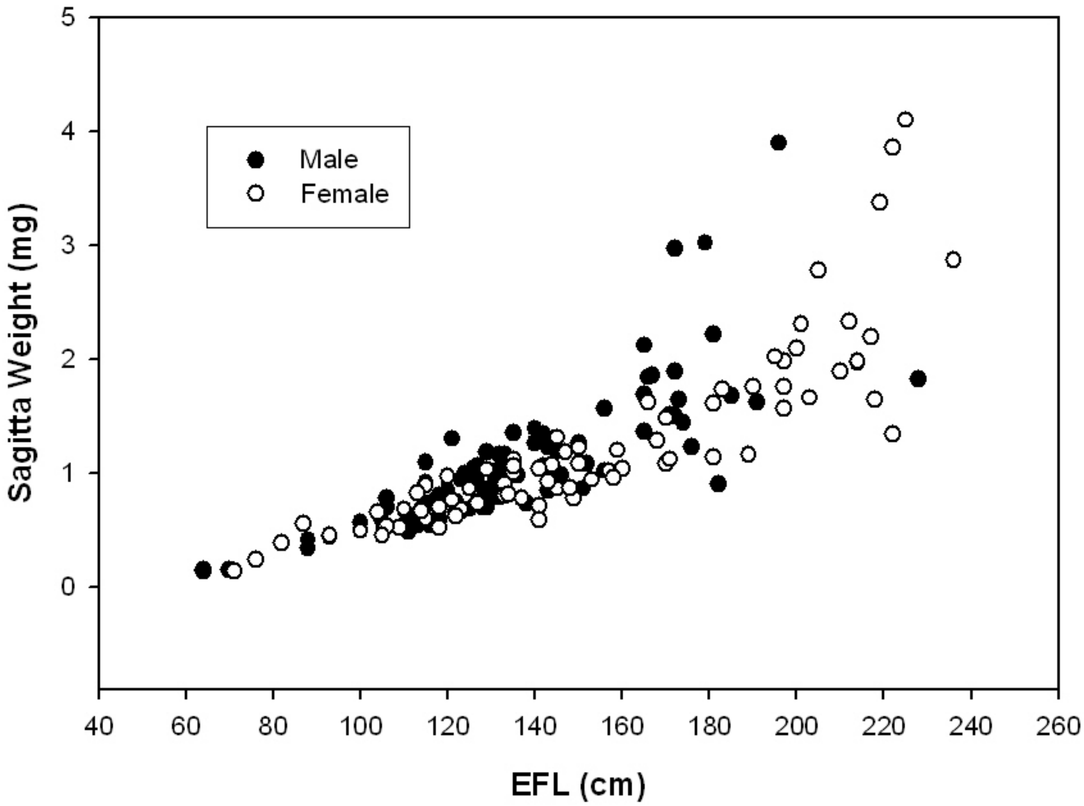

Figure 7.--Sagitta weight versus swordfish eye-to fork length for males (n = 91) and females (n = 82).

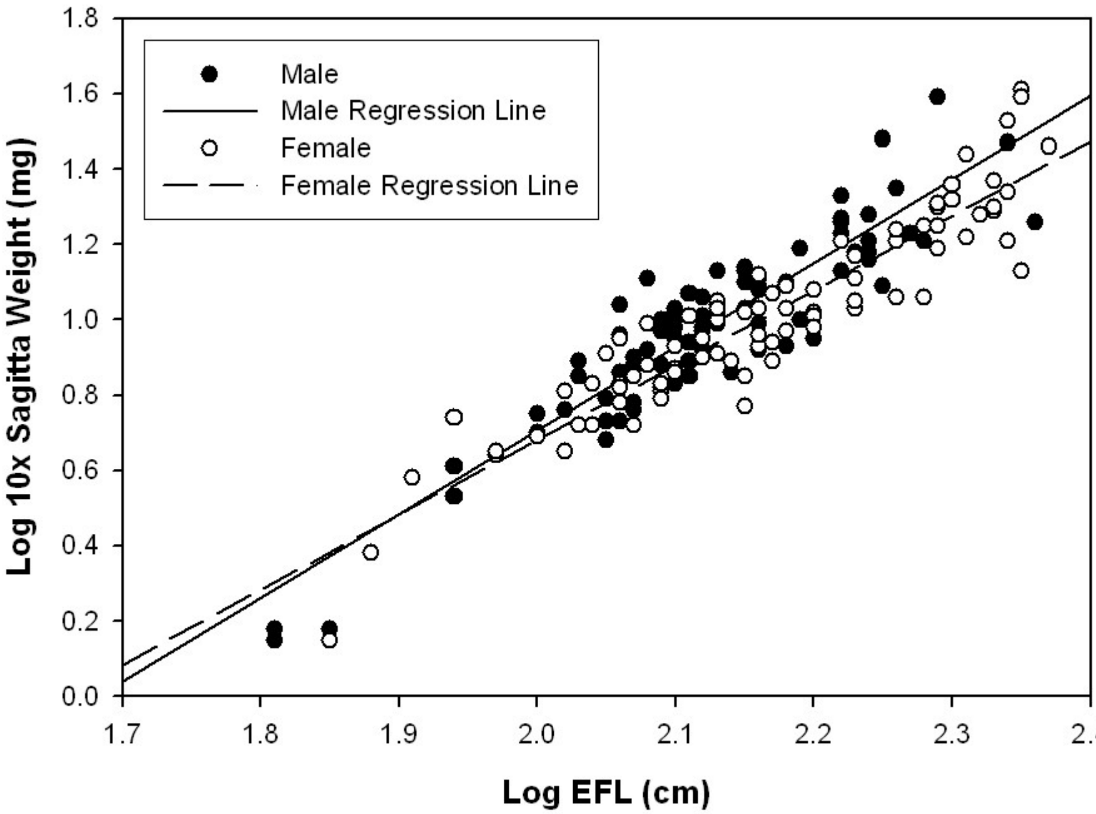

Figure 8.--Linear regressions of log sagitta weight (10x) versus log swordfish eye-to-fork length for males (n = 91) and for females (n = 82).

APPENDIX

List of swordfish samples used in the study. Age Group (Age Gp) in column 2 refers to the numbers of annuli that were counted as completely formed in sectioned sagittae. An "nd" in this column and all other columns indicates that data were not recorded. In column 4 (sex): "F" is for female, "M" is for male, and "unk" is for undetermined sex. Column 7 lists weights of the right sagitta in milligrams. Analogous information for the left sagitta is presented in column 8. In column 9 (SEM): a "yes" in this column indicates that one or both sagittae had been scanned with an electron microscope. In column 10 (Photo): a "yes" in this column means that a whole sagitta was photographed in liquid using a camera mounted on a dissecting microscope.

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
AAA 114	7	181	M	5	92				
ADP 15	17	202	M	4	94				
ADP 52	2	116	F	4	94				
ADP 108	6	177	F	5	94				
ADP 225	7	209	F	12	94				
ADP 232	nd	nd	nd	nd	nd				yes
ADP 233	6	210	F	12	94	1.92	1.86	yes	yes
ADP 238	7	229	F	12	94				
ADP 270	2	124	M	12	94		0.99	yes	yes
ADP 275	6	181	M	12	94				
ADP 348	nd	nd	nd	nd	nd				yes
ADP 365	9	215	F	2	95				
ADP 370	6	172	M	2	95	2.04	1.74	yes	yes
ADP 378	6	179	M	2	95	2.84	3.2	yes	yes
ADP 390	9	196	M	2	95				
ADP 396	12	219	M	2	95				
ADP 412	7	203	F	2	95				
ADP 439	7	189	M	2	95				
ADP 449	6	218	F	2	95	1.55	1.73	yes	yes
ADP 471	3	127	M	2	95	1.11	1	yes	yes
ADP 479	9	211	M	2	95				
ADP 488	4	168	M	2	95				
ADP 508	7	203	F	2	95				
ADP 537	1	129	M	3	95		0.7	yes	yes
ADP 539	6	174	M	3	95				
ADP 543	4	198	F	3	95				
ADP 547	4	151	M	3	95				
ADP 551	6	195	M	3	95				
ADP 552	5	158	M	3	95				
ADP 557	nd	110	F	3	95			yes	
ADP 558	1	123	F	3	95	0.66		yes	yes
ADP 560	6	183	F	3	95				
ADP 565	3	135	F	3	95	1	0.99	yes	yes
ADP 566	nd	107	F	3	95			yes	
ADP 567	5	213	F	3	95				
ADP 572	2	135	M	3	95		1.04	yes	yes
ADP 578	3	185	F	4	95				
ADP 582	6	197	F	4	95	2.07	1.89	yes	yes
ADP 599	nd	116	M	4	95			yes	
ADP 601	8	227	F	4	95				
ADP 605	1	122	F	4	95	0.65		yes	yes
ADP 613	8	200	F	4	95	2.04	2.14	yes	yes
ADP 630	5	208	F	4	95				
ADP 653	3	120	F	10	95	0.98	0.96	yes	yes
ADP 662	0	87	M	10	95	0.51	0.59	yes	yes
ADP 663	1	115	F	10	95	0.59	0.6	yes	yes
BBB 3	1	108	M	3	93				
BBB 4	1	106	F	3	93				
BBB 7	2	112	F	3	93				
BBB 17	0	77	unk	3	93				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
BBB 21	1	130	F	3	93				
BBB 27	6	157	F	3	93				
BBB 29	4	175	F	3	93				
BBB 31	2	125	F	3	93				
BBB 32	1	111	F	3	93				
BBB 34	1	96	F	3	93				
BBB 35	3	161	F	3	93				
BBB 36	1	94	F	3	93				
BBB 37	3	116	F	3	93				
BBB 44	3	153	M	4	93				
BBB 45	7	211	F	4	93				
BBB 47	2	132	M	4	93				
BBB 49	6	169	M	4	93				
BBB 54	4	162	M	4	93				
BBB 56	2	143	F	4	93				
BBB 58	4	121	M	4	93				
BBB 59	4	141	M	4	93				
BBB 60	1	81	unk	4	93				
BBB 62	2	107	F	4	93				
BBB 63	8	180	M	4	93				
BBB 65	1	108	F	4	93				
BBB 72	0	91	unk	4	93				
BBB 81	2	125	M	4	93				
BXM 56	0	88	M	4	96				
BXM 61	1	109	M	4	96				
BXM 63	5	215	F	4	96				
BXM 72	1	111	M	6	96				
BXM 79	2	153	M	6	96				
BXM 85	2	102	M	10	96				
BXM 88	1	97	F	10	96				
BXM 103	3	208	F	3	97				
BXM 109	2	103	M	3	97				
BXM 121	0	96	F	3	97				
BXM 122	4	203	F	3	97				
BXM 134	1	105	M	3	97				
BXM 147	11	226	F	3	97				
BXM 149	1	104	F	3	97				
BXM 159	7	207	F	3	97				
BXM 166	3	160	F	4	97				
BXM 174	7	223	F	5	97				
BXM 177	2	100	M	5	97				
BXM 183	1	97	F	5	97				
BXM 184	7	211	F	5	97				
BXM 187	0	136	F	5	97				
BXM 188	0	97	M	5	97				
BXM 192	2	118	M	5	97				
BXM 193	3	170	F	5	97				
BXM 194	4	154	F	5	97				
BXM 197	4	166	F	5	97				
BXM 200	4	196	F	5	97				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
BXM 201	7	173	M	5	97				
BXM 206	1	138	M	5	97				
BXM 210	5	181	F	5	97				
BXM 211	1	113	M	5	97				
BXM 213	6	202	F	5	97				
BXM 214	7	170	M	5	97				
BXM 215	10	202	M	5	97				
BXM 216	3	164	F	5	97				
BXM 218	3	158	F	5	97				
BXM 219	8	197	F	5	97				
BXM 222	0	96	F	5	97				
BXM 224	4	177	M	5	97				
BXM 227	6	204	F	5	97				
BXM 228	10	247	F	5	97				
BXM 229	8	220	F	5	97				
BXM 230	5	182	M	5	97				
BXM 231	1	121	F	5	97				
BXM 233	1	111	M	5	97				
BXM 235	7	229	F	5	97				
BXM 236	0	93	F	5	97				
BXM 237	8	210	F	5	97				
BXM 239	5	195	F	5	97				
BXM 240	2	124	M	5	97				
BXM 244	3	157	M	5	97				
BXM 252	0	53	M	9	97				
BXM 261	6	197	F	12	97				
BXM 266	6	210	F	12	97				
BXM 267	11	210	M	12	97				
BXM 268	4	180	F	12	97				
BXM 301	9	212	M	1	98				
BXM 303	6	187	F	1	98				
BXM 304	5	240	F	1	98				
BXM 309	4	205	F	1	98				
BXM 310	8	200	M	1	98				
BXM 312	6	201	F	1	98				
BXM 314	6	200	F	1	98				
CSF 1	5	163	M	5	96				
CSF 2	4	179	F	5	96				
CSF 6	3	154	F	6	96				
CSF 7	8	224	F	6	96				
CSF 11	5	158	F	6	96				
CSF 12	5	153	M	6	96				
CSF 13	0	87	F	6	96				
CSF 14	3	158	F	6	96				
CSF 15	0	81	F	6	96				
CSF 16	1	82	F	6	96				
CSF 19	1	148	M	6	96				
CSF 22	0	81	F	6	96				
CSF 23	7	161	M	6	96				
CSF 30	8	200	F	7	96				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
CSF 33	7	173	M	7	96				
CSF 46	8	200	F	7	96				
CSF 51	7	205	F	7	96				
CSF 54	10	212	F	7	96				
CSF 56	11	205	F	7	96				
CSF 63	4	154	F	11	96				
CSF 66	1	141	F	12	96				
CSF 67	2	133	F	12	96	0.9			
CSF 69	1	111	M	12	96		0.62		
CSF 70	1	100	M	12	96				
CSF 71	0	81	M	12	96				
CSF 72	1	141	F	12	96	0.7	0.72		
CSF 85	11	218	F	2	97				
CSF 91	9	199	F	2	97				
DAW 10	nd	92	M	3	94			yes	
DAW 11	nd	100	M	3	94			yes	
DAW 48	5	204	F	4	94				
DAW 53	nd	118	M	4	94	0.6			
DAW 55	7	211	F	4	94				
DAW 57	nd	128	M	4	94	0.7		yes	yes
DAW 58	3	205	F	4	94				
DAW 62	nd	203	F	4	94			yes	
DAW 68	nd	118	M	4	94	0.8			
DAW 73	2	128	M	4	94	0.77		yes	yes
DAW 74	nd	146	M	4	94			yes	
DBK 67	1	126	F	6	94				
DBK 69	9	162	M	6	94				
DBK 104	nd	nd	nd	8	94			yes	
DBK 106	nd	98	M	8	94			yes	
DBK 142	4	151	M	10	94				
DBK 233	3	142	M	3	95	1.34	1.34	yes	yes
DBK 234	nd	107	F	3	95			yes	
DBK 235	nd	nd	nd	3	95			yes	
DBK 237	3	153	F	3	95	0.86	1.02	yes	yes
DBK 240	nd	133	M	3	95	1.16	1.12		
DBK 243	3	127	M	3	95	0.89	0.9	yes	yes
DBK 245	3	151	M	3	95	0.81	0.92	yes	yes
DBK 246	4	145	M	3	95	1.2	1.18	yes	yes
DBK 248	nd	103	M	3	95			yes	
DBK 253	3	145	F	3	95	1.31		yes	yes
DBK 254	nd	nd	nd	3	95			yes	
DBK 255	2	131	M	3	95	0.84		yes	yes
DBK 259	2	132	M	3	95	0.78	0.8	yes	yes
DXR 12	9	229	F	3	97				
DXR 14	12	245	F	3	97				
DXR 16	6	200	F	3	97				
DXR 19	9	216	F	3	97				
DXR 23	7	203	F	3	97				
DXR 24	13	259	F	3	97				
DXR 27	11	214	F	3	98				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
ECF 2	4	158	M	5	96				
ECF 5	10	210	M	5	96				
ECF 6	3	132	F	5	96				
ECF 7	11	194	M	5	96				
ECF 9	0	100	M	5	96				
ECF 11	2	122	M	5	96				
ECF 12	1	95	M	5	96				
ECF 13	0	83	M	5	96				
ECF 14	0	96	F	5	96				
ECF 16	4	164	M	5	96				
ECF 17	0	91	M	5	96				
ECF 19	0	105	M	5	96				
ECF 20	0	97	F	5	96				
ECF 21	0	94	F	5	96				
ECF 24	0	93	M	5	96				
ECF 27	0	96	F	5	96				
ECF 28	0	96	M	5	96				
ECF 29	0	94	M	6	96				
ECF 30	1	92	M	6	96				
ECF 59	5	144	M	8	96	1.4	1.21		
ECF 60	7	172	M	8	96	1.47	1.53		
ECF 63	0	87	M	8	96				
ECF 64	7	195	F	8	96	2	2.04		
ECF 67	0	95	F	8	96				
ECF 72	5	150	F	8	96	1.2	0.96		
ECF 75	2	141	F	8	96		0.59		
ECF 81	3	130	M	8	96	0.92	0.82		
ECF 87	0	82	F	8	96				
ECF 88	1	115	F	8	96	0.88	0.9		
ECF 103	2	120	M	8	96	0.84	0.84	yes	yes
ECF 106	1	109	F	8	96	0.52	0.53		
ECF 108	1	113	F	1	97				
ECF 109	10	208	F	1	97				
ECF 115	11	204	F	1	97				
ECF 139	10	223	F	2	97				
ECF 172	1	134	F	2	98				
ECF 173	4	181	F	2	98				
ECF 174	2	124	M	2	98				
ECF 175	2	127	F	2	98				
ECF 176	3	145	F	2	98				
ECF 177	3	133	M	2	98				
ECF 178	4	208	F	2	98				
ECF 179	4	194	F	2	98				
ECF 180	2	200	F	2	98				
ECF 181	0	126	M	2	98				
ECF 182	3	107	M	2	98				
ECF 183	4	179	F	2	98				
ECF 184	6	198	M	2	98				
ECF 185	1	118	M	2	98				
ECF 186	0	116	F	2	98				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
ECF 187	3	138	M	2	98				
ECF 189	2	116	M	2	98				
ECF 190	2	127	F	2	98				
ECF 191	6	193	F	2	98				
ECF 192	0	112	M	2	98				
ECF 193	1	116	F	2	98				
ECF 194	1	118	M	2	98				
ECF 195	2	114	M	2	98				
ECF 196	2	118	F	2	98				
ECF 197	5	182	F	2	98				
ECF 198	0	78	M	2	98				
ECF 199	4	165	F	2	98				
ECF 200	1	117	M	2	98				
ECF 204	7	214	F	4	98				
ECF 205	6	204	F	4	98				
ECF 237	18	201	M	5	98				
EDL 16	7	201	F	7	98				
EDL 28	7	201	F	8	98				
EDL 38	16	210	F	8	98				
EDL 43	16	250	F	8	98				
HMY 38	9	222	F	3	96				
HMY 41	14	194	M	3	96				
HMY 85	11	177	M	3	96				
JED 34	4	182	M	10	94				
JED 147	nd	112	M	3	95			yes	
JED 166	2	131	M	3	95		0.95	yes	yes
JED 185	9	236	F	3	95				
JED 187	2	135	M	3	95	1.1		yes	yes
JED 205	nd	123	F	3	95	0.67	0.7		
JED 242	5	133	M	3	95	1.12	1.21	yes	yes
JED 276	5	159	F	3	95	1.25	1.16	yes	yes
JED 277	2	189	F	3	95	1.16	1.16	yes	yes
JED 278	2	137	F	3	95	0.78	0.78	yes	yes
JED 291	2	136	M	3	95	1	0.96	yes	yes
JED 292	3	181	F	3	95	1.58	1.64	yes	yes
JED 323	1	118	M	5	95	0.58	0.59	yes	yes
JED 333	1	118	M	5	95	0.72	0.76	yes	yes
JED 335	2	127	F	5	95	0.75	0.74	yes	yes
JED 336	3	134	M	5	95	1.08	1.02	yes	yes
JED 338	3	126	M	5	95	1		yes	yes
JED 340	2	133	F	5	95		0.8	yes	yes
JED 342	3	132	M	5	95		1.16	yes	yes
JED 345	nd	115	M	5	95	0.86	0.96		
JJB 20	3	111	F	6	95				
KDB 155	nd	147	F	4	95	1.16	1.2		
KDB 156	nd	149	F	4	95	0.84	0.71		
KDB 162	2	116	M	4	95	0.78	0.68	yes	yes
KDB 168	9	193	M	4	95				
KDB 169	nd	146	M	4	95	0.92	1.03		
KDB 170	11	214	F	4	95				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
KDB 174	7	200	F	4	95				
KDB 178	1	114	F	4	95		0.68		
KDB 185	3	144	F	4	95	1.06	1.08	yes	yes
KDB 186	2	123	M	4	95	0.93	0.96	yes	yes
KDB 187	10	201	F	4	95	2.33	2.29	yes	yes
KDB 188	nd	113	M	4	95		0.54		
KDB 190	1	114	F	4	95	0.64	0.68	yes	yes
KDB 193	7	205	F	4	95	2.58	2.98	yes	yes
KDB 196	3	166	F	4	95	1.64	1.59	yes	yes
KDB 197	11	208	F	5	95				
KDB 203	6	190	F	5	95				
KDB 208	1	106	F	5	95	0.52	0.54	yes	yes
KDB 214	3	115	M	5	95	0.72			
KDB 220	3	129	M	5	95	1.18	1.18	yes	yes
KDB 227	1	118	M	5	95	0.75	0.78		
KDB 228	4	160	F	5	95	0.94	1.15	yes	yes
KDB 238	6	162	M	5	95				
KDB 244	2	135	F	5	95	1.12		yes	yes
KDB 246	11	197	F	5	95				
KDB 316	nd	76	F	11	95	0.22	0.27	yes	yes
KXH 106	6	165	M	1	96				
LEV 82	6	215	F	5	94				
LEV 91	9	192	M	5	94				
LEV 107	nd	88	M	9	94			yes	
LEV 117	nd	65	M	9	94			yes	
LEV 133	nd	101	F	9	94			yes	
LEV 134	nd	90	F	9	94			yes	
LEV 137	nd	58	M	9	94			yes	
LEV 139	nd	68	M	9	94			yes	
LEV 140	nd	94	M	9	94			yes	
LEV 141	nd	99	F	9	94			yes	
LEV 144	nd	93	M	9	94			yes	
LEV 146	nd	100	M	9	94			yes	
LEV 148	nd	102	M	9	94			yes	
LEV 161	nd	nd	nd	nd	nd			yes	
LEV 165	nd	75	F	11	94			yes	
LEV 166	nd	71	F	11	94			yes	
LEV 167	nd	72	F	11	94			yes	
LEV 168	nd	73	M	11	94			yes	
LEV 169	nd	nd	nd	1	95				yes
LEV 170	7	181	M	1	95	2.09	2.34	yes	yes
LEV 171	nd	104	F	1	95		0.65		
LEV 175	5	203	F	1	95	1.63	1.69	yes	yes
LEV 180	3	170	F	1	95	1.13	1.04	yes	yes
LEV 187	8	190	F	1	95	1.78	1.75	yes	yes
LEV 191	nd	180	M	1	95				yes
LEV 194	8	209	F	1	95				
LEV 204	nd	143	M	1	95	1.2	1.26		
LEV 221	5	222	F	1	95	1.03	1.66	yes	yes
LEV 223	6	227	F	1	95				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
LEV 232	9	219	F	1	95	3.32	3.44	yes	yes
LEV 310	4	167	M	1	95	1.8	1.92	yes	yes
LEV 311	nd	145	F	1	95	0.84	0.88		
LEV 313	nd	147	M	1	95			yes	
LEV 315	nd	157	F	1	95	0.97	1.06		
LEV 316	11	202	M	1	95				
LEV 326	9	212	F	4	95				
LEV 355	8	227	F	4	95				
LEV 359	7	182	M	4	95				
LEV 365	11	224	F	4	95				
LEV 368	13	231	F	4	95				
LEV 412	10	191	M	4	95				
LEV 419	5	182	F	4	95				
LEV 515	13	221	F	6	95				
LEV 520	nd	111	M	6	95	0.48	0.48		
LEV 524	3	125	M	6	95	0.92	0.98	yes	yes
LEV 525	7	166	F	6	95				
LEV 526	0	87	F	6	95	0.56	0.54	yes	yes
LEV 527	0	88	M	6	95	0.44	0.38	yes	yes
LEV 532	2	118	F	6	95	0.73	0.66	yes	yes
LEV 535	1	131	M	6	95	1.08	0.97		
LEV 537	13	240	F	6	95				
LEV 539	2	131	M	6	95	0.9	0.88	yes	yes
LEV 541	nd	135	F	6	95	1.06	1.05		
LEV 543	nd	118	F	6	95		0.52		
LEV 544	0	82	F	6	95	0.39	0.36		
LEV 562	0	106	M	6	95	0.72	0.67	yes	
LEV 569	1	125	M	6	95	0.68	0.69	yes	yes
LEV 570	0	88	M	6	95	0.34	0.34		
LEV 579	4	162	F	6	95				
LEV 582	2	115	M	6	95	1.06	1.12	yes	yes
LEV 586	2	133	M	6	95	0.92	0.94	yes	yes
LEV 618	nd	71	F	10	95	0.14		yes	yes
LEV 619	nd	70	M	10	95	0.14	0.16	yes	yes
LEV 626	0	63	F	5	96				
LEV 629	0	66	F	5	96				
LEV 666	6	181	F	2	97				
LEV 670	10	202	F	2	97				
LEV 671	7	181	F	2	97				
LEV 672	12	223	F	2	97				
LEV 692	7	195	M	2	98				
LEV 694	6	201	F	2	98				
LSE 23	3	145	F	5	96				
LSE 28	3	131	M	5	96				
LSE 29	4	139	F	5	96				
LSE 30	3	125	M	5	96				
LSE 31	3	128	M	5	96				
LSE 33	3	150	M	5	96				
LSE 35	2	136	M	5	96				
LSE 36	2	123	M	5	96				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
LSE 37	3	130	M	5	96				
LSE 40	5	171	M	5	96				
LSE 44	0	106	M	5	96				
LSE 49	6	224	F	5	96				
NLA 5	5	187	F	6	96				
NLA 26	5	200	F	6	96				
NLA 31	3	127	M	8	96		1		
NLA 33	3	121	M	8	96	1.3		yes	yes
NLA 46	3	125	F	8	96		0.86		
NLA 233	3	150	M	12	96		1.26		
NLA 248	3	170	F	12	96		1.48		
NLA 250	4	185	M	12	96	1.68			
NLA 255	2	122	M	12	96		0.75		
NLA 283	2	127	F	12	96	0.73			
NLA 286	5	183	F	12	96	1.73			
NLA 292	2	182	M	12	96	0.9			
NLA 316	13	213	F	4	97				
NLA 341	12	214	F	4	97				
NLA 343	10	214	F	5	97				
NLA 344	9	212	F	5	97				
NLA 353	8	212	F	5	97				
NLA 362	11	224	F	5	97				
RGH 211	2	158	F	8	95		0.96		
RGH 216	4	164	F	8	95				
RGH 217	5	140	M	8	95	1.39			
RGH 218	3	152	M	9	95	1.08			
RGH 222	0	93	F	9	95	0.45	0.44	yes	yes
RGH 223	nd	113	F	9	95		0.82	yes	yes
RGH 224	0	93	F	9	95	0.45	0.45	yes	yes
RGH 238	0	81	F	2	96				
RGH 247	2	127	M	6	96				
RGH 248	3	109	M	6	96				
RGH 249	7	185	F	6	96				
RGH 250	0	61	M	6	96				
RGH 253	0	95	F	7	96				
RGH 254	6	171	F	7	96				
RGH 261	0	79	F	7	96				
RGH 272	23	217	M	7	96				
RGH 275	11	204	F	7	96				
RGH 278	0	92	M	7	96				
RGH 281	0	95	M	7	96				
RGH 284	4	133	M	11	96	0.9			
RGH 288	4	137	F	11	96				
RGH 293	4	129	F	11	96	1.04	1.02		
RGH 296	0	71	M	11	96				
RGH 297	2	143	F	11	96	0.92	0.92		
RGH 300	3	122	F	11	96				
RGH 301	4	158	F	11	96				
RGH 304	3	138	M	11	96	0.73	0.73		
RGH 307	3	143	F	11	96				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
RGH 308	4	148	F	11	96	0.86	0.88		
RGH 310	7	214	F	11	96	1.94	2		
RGH 313	4	160	F	11	96				
RGH 314	5	149	F	11	96				
RGH 322	2	151	F	11	96				
RGH 323	3	139	M	11	96				
RGH 327	4	158	F	11	96				
RGH 333	1	91	M	11	96				
RGH 336	1	91	F	11	96				
RGH 337	3	106	M	11	96	0.78	0.78		
RGH 339	3	170	F	11	96				
RGH 345	10	181	M	11	96				
RGH 355	6	167	M	11	96				
RGH 357	5	176	F	11	96				
RGH 373	4	166	F	11	96				
RGH 383	0	108	F	11	96				
RGH 384	0	94	F	11	96				
RGH 385	0	87	F	11	96				
RGH 386	0	72	F	11	96				
RGH 390	0	80	M	11	96				
RGH 391	7	197	F	11	96	1.76			
RGH 393	17	225	F	11	96	4	4.19		
RGH 396	12	212	F	11	96	2.26	2.4		
RGH 398	12	222	F	12	96		3.86		
RGH 400	3	140	M	12	96	1.25	1.26		
RGH 401	4	146	M	12	96				
RGH 402	1	112	M	12	96				
RGH 403	1	97	F	12	96				
RGH 404	6	174	M	12	96	1.44			
RGH 405	0	96	M	12	96				
RGH 406	1	111	M	12	96				
RGH 407	1	100	M	12	96	0.5	0.5		
RGH 408	1	105	M	12	96	0.57			
RGH 409	0	105	F	12	96	0.52	0.38		
RGH 423	10	163	M	2	97				
RGH 433	0	70	M	2	97				
RGH 449	6	205	F	2	97				
RGH 493	4	163	F	3	97				
RGH 514	7	229	F	4	97				
RGH 522	9	222	F	4	97				
RGH 531	2	93	F	4	97				
RGH 536	5	206	F	4	97				
RGH 545	0	63	unk	10	97				
SJA 140	nd	108	M	3	95			yes	
SJA 143	nd	121	M	3	95			yes	
SJA 149	nd	109	F	3	95			yes	
SJA 151	10	222	F	3	95			yes	
SJA 155	2	126	M	4	95	1.04		yes	yes
SJA 158	12	200	M	4	95				
SJA 161	9	226	F	4	95			yes	

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
SJA 167	6	217	F	4	95				
SJA 179	nd	113	M	4	95			yes	
SJA 185	4	135	M	4	95	1.42	1.28	yes	yes
SJA 188	nd	236	F	4	95	2.98	2.76	yes	yes
SJA 206	3	181	F	4	95	1.26	1.03	yes	yes
SJA 215	6	214	F	4	95	2	1.95	yes	yes
SJA 285	nd	165	M	7	95	1.76	1.62	yes	yes
SJA 291	nd	156	M	7	95	1.62	1.5		
SJA 294	6	166	M	7	95	1.84		yes	yes
SJA 306	4	168	F	7	95	1.28		yes	yes
SJA 319	4	217	F	7	95	2.14	2.24	yes	yes
SJA 322	4	165	M	7	95		2.12	yes	yes
SJA 327	5	171	M	7	95				
SJA 332	9	172	M	7	95	2.96	2.98		
SJA 334	nd	141	F	7	95	1.02	1.06		
SJA 345	nd	143	M	7	95	0.86	0.81		
SJA 353	5	197	F	7	95	1.52	1.59	yes	yes
SJA 363	15	196	M	7	95	3.9	3.9	yes	yes
SJA 364	nd	171	F	7	95	1.12	1.11	yes	yes
SJA 366	3	173	M	7	95	1.65	1.62	yes	yes
SJA 374	nd	150	F	7	95	1.24	1.21		
SJA 396	13	249	F	1	96				
SJA 514	13	204	F	3	96				
SJA 593	7	224	F	4	96				
SJA 600	4	170	F	4	96				
SJA 633	3	152	F	11	96				
SJA 634	7	186	F	11	96				
SJA 635	5	157	M	11	96				
SJA 649	1	100	M	11	96	0.56			
SJA 658	4	171	M	11	96	1.68	1.34		
SJA 661	3	156	M	11	96	1.02	1		
SJA 662	3	142	M	11	96	1.04	1.08		
SJA 672	7	191	M	11	96	1.62			
SJA 674	3	171	M	11	96				
SJA 676	4	190	F	11	96				
SJA 683	0	100	F	11	96	0.46	0.52		
SJA 698	3	155	M	11	96				
SJA 699	4	193	F	11	96				
SJA 705	1	116	F	11	96				
SJA 707	1	116	M	11	96		0.54		
SJA 709	1	110	F	11	96	0.72	0.64		
SJA 711	5	193	F	11	96				
SJA 715	5	176	M	11	96	1.23			
SJA 716	7	209	F	11	96				
SJA 726	8	190	F	11	96				
SJA 749	5	161	F	11	96				
SJA 753	1	122	F	11	96	0.62			
SJA 777	11	228	M	11	96		1.82		
SJA 792	12	225	F	3	97				
SJA 796	8	207	F	3	97				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
SJA 800	6	219	F	3	97				
SJA 818	5	190	F	4	97				
SJA 819	3	143	M	4	97				
SJA 820	3	180	F	4	97				
SJA 821	6	191	F	4	97				
SJA 823	9	216	F	4	97				
SJA 825	1	99	F	4	97				
SJA 826	1	135	M	4	97				
SJA 828	7	207	F	4	97				
SJA 829	2	116	M	4	97				
SJA 830	4	144	M	4	97				
SJA 831	2	165	F	4	97				
SJA 834	4	164	F	4	97				
SJA 837	2	105	M	4	97				
SJA 838	10	217	F	4	97				
SJA 839	1	127	F	4	97				
SJA 841	7	184	F	4	97				
SJA 842	5	198	F	4	97				
SJA 843	4	183	F	4	97				
SJA 845	2	145	F	4	97				
SJA 846	5	153	F	4	97				
SJA 848	3	163	F	4	97				
SJA 850	3	166	F	4	97				
SJA 851	3	193	F	4	97				
SJA 852	3	173	F	4	97				
SJA 853	11	247	F	4	97				
SJA 854	4	170	F	4	97				
SJA 855	3	137	M	4	97				
SJA 874	7	210	F	5	98				
SSO 1	nd	64	M	10	95			yes	
SSO 2	nd	67	F	10	95			yes	
SSO 3	nd	66	unk	10	95			yes	
SSO 4	nd	75	unk	10	95			yes	
SSO 5	nd	68	unk	10	95			yes	
SSO 6	nd	58	unk	10	95			yes	
SSO 7	0	58	M	10	96				
SSO 8	0	55	M	10	96				
SSO 10	nd	64	M	10	96	0.15		yes	yes
SSO 12	nd	64	M	10	96		0.14	yes	yes
SSO 14	0	63	F	10	96				
SSO 15	0	56	F	10	96				
SSO 16	0	74	F	10	96				
SSO 17	0	60	F	10	96				
SSO 18	0	74	F	10	96				
SSO 39	0	63	F	4	97				
SSO 44	0	52	F	9	97				
SSO 45	0	58	F	9	97				
SSO 46	0	62	M	9	97				
SSO 47	0	68	F	9	97				
SSO 53	0	65	M	9	97				

Sample #	Age Gp	EFL (cm)	Sex	Cap. mo.	Cap. yr.	Rsag. wt. (mg)	Lsag. wt. (mg)	SEM	Photo
SSO 54	0	61	F	9	97				
SWH 45	nd	97	M	10	94			yes	
SWH 52	7	170	M	5	95				
TEM 31	6	202	F	5	96				
TEM 32	4	209	F	5	96				
TEM 33	0	95	M	5	96				
TEM 34	1	152	M	5	96				
TEM 35	7	202	F	5	96				
TEM 40	5	190	F	5	96				
TEM 41	5	186	F	5	96				
TEM 42	1	98	M	5	96				
TEM 43	0	93	F	5	96				
TEM 45	4	189	F	5	96				
TEM 48	0	98	M	5	96				
TEM 49	0	92	M	5	96				
TEM 52	0	139	M	5	96				
TEM 53	1	95	M	5	96				
TEM 55	5	204	F	5	96				
TEM 57	0	97	F	5	96				
TLR 99	3	134	M	7	94	1.06		yes	yes
TLR 116	10	221	F	11	94				
TLR 130	5	152	F	11	94				
TLR 141	9	180	M	11	94				
TLR 143	nd	nd	nd	nd	nd			yes	